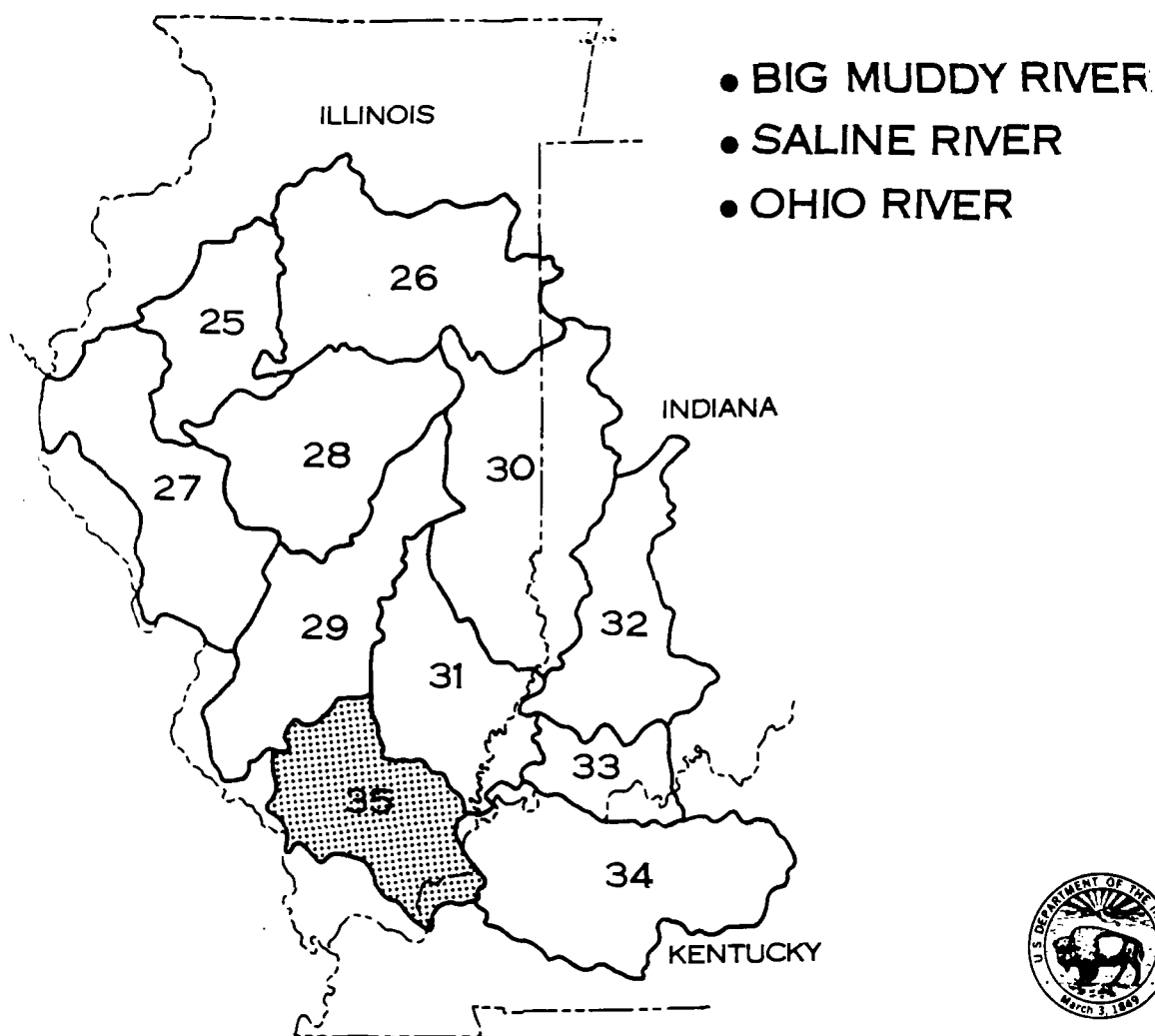




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HYDROLOGY OF AREA 35, EASTERN REGION, INTERIOR COAL PROVINCE, ILLINOIS AND KENTUCKY



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 81-403

HYDROLOGY OF AREA 35, EASTERN REGION, INTERIOR COAL PROVINCE, ILLINOIS AND KENTUCKY

BY

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**U.S. GEOLOGICAL SURVEY
WATER-RESOURCES INVESTIGATIONS 81-403**



**URBANA, ILLINOIS
MAY 1981**

8.0 SURFACE WATER (Continued)
 8.2 SURFACE-WATER QUALITY (Continued)
 8.2.4 IRON

IRON CONCENTRATIONS ARE HIGHER DOWNSTREAM THAN UPSTREAM OF MINING

Dissolved iron ranged from 0 to 640 micrograms per liter ($\mu\text{g/L}$) at sites upstream of mining and from 0 to 1,100,000 $\mu\text{g/L}$ at sites downstream of mining. Total recoverable iron ranged from 100 to 31,000 $\mu\text{g/L}$ at the upstream sites and from 0 to 2,100,000 $\mu\text{g/L}$ at the downstream sites.

Iron is the fourth most abundant element in the Earth's crust with 4.7 percent (Petrucci, 1972). It is an important constituent of the surface and ground waters in this area because of its abundance in the sedimentary rocks of the Pennsylvanian System. Under natural conditions, in sedimentary rock and ground water, iron is found primarily in the ferrous form (Fe^{+2}). It is the abundance and the instability of ferrous iron, when exposed to air, that probably influence many chemical reactions downstream of mining. Surface-mining processes increase the amount of iron available to the system by exposing more surface area of iron-bearing minerals to weathering conditions. Geologic and erosional factors at sites upstream of mining maintain fairly stable concentrations of iron in streams.

At sites upstream of mining, the measured range of concentration for dissolved iron was from 0 to 640 $\mu\text{g/L}$ with a mean of about 110 $\mu\text{g/L}$. At sites downstream of

mining, concentrations of dissolved iron ranged from 0 to 1,100,000 $\mu\text{g/L}$ with a mean of about 20,000 $\mu\text{g/L}$ or approximately 20 milligrams per liter (mg/L) (fig. 8.2.4-1 and 8.2.4-2 and table 8.2.4-1).

Total recoverable iron for the sites upstream of mining ranged from 100 to 31,000 $\mu\text{g/L}$ with a mean of about 2,400 $\mu\text{g/L}$. Total recoverable iron for the downstream sites ranged from 0 to 2,100,000 $\mu\text{g/L}$ with a mean of about 37,800 $\mu\text{g/L}$ or approximately 38 mg/L (fig. 8.2.4-1 and 8.2.4-3 and table 8.2.4-2).

Concentrations of dissolved iron in surface water seldom reach 1 mg/L (American Public Health Association, 1976, p. 207). For the upstream sites, the entire range of values is well below this level. The surface water of areas downstream of mining sometimes exceeded 1 mg/L of dissolved iron.

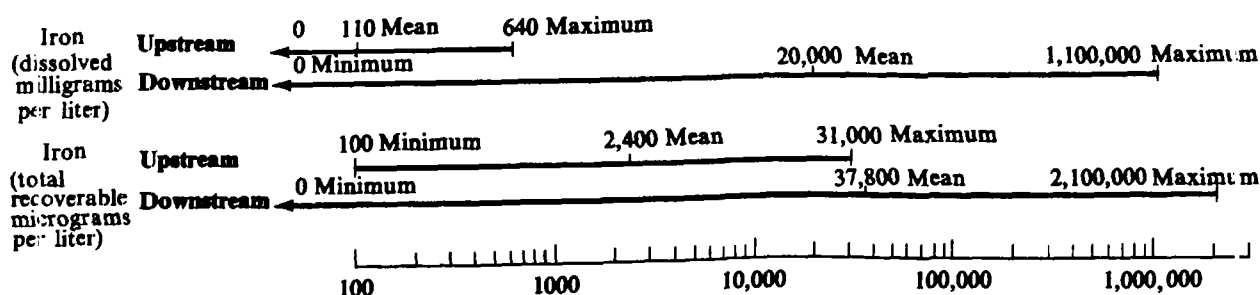


Figure 8.2.4-1 Range of dissolved iron and total recoverable iron concentrations measured at sites upstream and downstream of mining

8.0 SURFACE WATER (Continued)

8.2 SURFACE-WATER QUALITY (Continued)

8.2.5 MANGANESE

CONCENTRATIONS OF DISSOLVED AND TOTAL RECOVERABLE MANGANESE ARE HIGHER DOWNSTREAM THAN UPSTREAM OF MINING

Mean values of dissolved and total recoverable manganese concentrations were approximately 7 to 10 times greater at the sites downstream of mining than at the upstream sites.

Manganese is a common element widely distributed in igneous rocks and soils, but its total abundance in the Earth's crust is small enough to put it in the list of "trace" elements. Manganese and iron have similar electronic configurations and behave similarly. Because manganese has a lower affinity for oxygen, it stays in solution longer than iron (Rankama and Sahama, 1950).

For the sites upstream of mining in the study area, the measured concentrations of dissolved manganese ranged from 30 to 4,900 micrograms per liter ($\mu\text{g/L}$) with a mean of about 560 $\mu\text{g/L}$. This compares to a measured range of 20 to 91,000 $\mu\text{g/L}$ and a mean of about 4,100 $\mu\text{g/L}$ for the sites downstream of mining (fig. 8.2.5-1 and 8.2.5-2 and table 8.2.5-1).

Total recoverable manganese for the sites upstream of mining ranged from 30 to 3,900 $\mu\text{g/L}$ with a mean of

about 570 $\mu\text{g/L}$. Downstream of mining the measured values of total recoverable manganese ranged from 20 to 240,000 $\mu\text{g/L}$ with a mean of about 5,590 $\mu\text{g/L}$ (fig. 8.2.5-1 and 8.2.5-3 and table 8.2.5-2).

According to Rankama and Sahama (1950) the Mn:Fe ratio in natural carbonate waters is about 5:1. This ratio is approximated by the upstream data for which the mean dissolved manganese value was 560 $\mu\text{g/L}$ and the mean dissolved iron value was 110 $\mu\text{g/L}$. The mean values of dissolved manganese and dissolved iron for the downstream sites are 4,100 $\mu\text{g/L}$ and 20,000 $\mu\text{g/L}$, respectively, resulting in a Mn:Fe ratio of 0.21:1. This decrease in the Mn:Fe ratio reflects the relatively large upstream to downstream increase in iron concentrations compared to manganese concentrations.

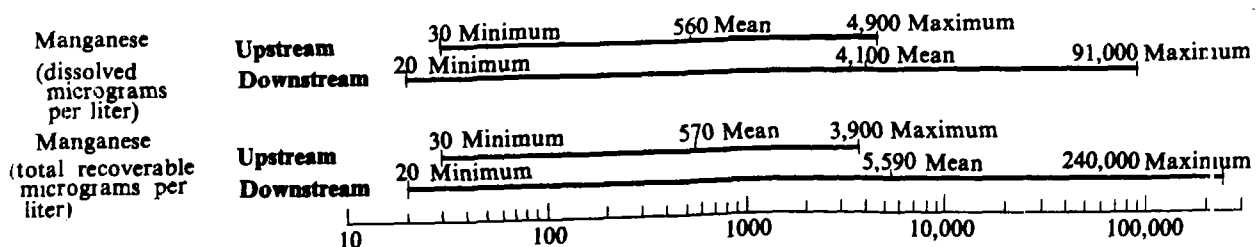


Figure 8.2.5-1 Range of dissolved and total recoverable manganese concentrations measured at sites upstream and downstream of mining

8.0 SURFACE WATER (Continued)
8.2 SURFACE-WATER QUALITY (Continued)
8.2.6 SULFATE

**SULFATE CONCENTRATIONS ARE HIGHER DOWNSTREAM
THAN UPSTREAM OF MINING**

Concentrations of sulfate ranged from 12 to 500 milligrams per liter (mg/L) at the sites upstream of mining and from 15 to 12,000 mg/L at the downstream sites. Sulfate concentrations at downstream sites can be estimated using the equation:
 $SULFATE = 0.64 (SPECIFIC\ CONDUCTANCE) - 210$

Sulfur occurs in the coal and associated strata as metallic sulfides, mainly in the form of pyrite (FeS_2) and marcasite (FeS_2), which are also sources of ferrous iron. When oxidized, the sulfides yield the sulfate ion and ferric oxide. At the sites upstream of mining, the sulfates are probably introduced to the water from stream cuts through exposed Pennsylvanian rocks. This would be a fairly steady source of sulfate with erosion and oxidation contributing to the dissolution of sulfate materials.

The measured concentrations of sulfate at the upstream sites range from 12 to 500 mg/L with a mean value of 140 mg/L for all the observations at all the upstream sites. The upstream sulfate data contrast sharply with sulfate data for the downstream sites (table 8.2.6-1). The mean downstream sulfate value of 760 mg/L is larger than any value at an upstream site, and the maximum value of 12,000 mg/L is 24 times that of the largest value found at an upstream site (fig. 8.2.6-1). The minimum sulfate value of 15 mg/L at the downstream sites is approximately the same as the minimum at the upstream sites.

The contrast in sulfate concentrations between the sites upstream and downstream of mining, as seen in figure 8.2.6-2, suggests the higher sulfate concentrations downstream of mining probably result from the increased exposure of sulfide-bearing minerals to weathering in the mined area. Toler (1980) related annual sulfate loads to the area of surface mines as a percentage of total drainage area and showed that in southern Illinois sulfate can be used as an indicator of mine drainage (fig. 8.2.6-3).

For the sites downstream of mining a comparison was made between sulfate concentrations and specific conductance. There is a strong correlation (correlation coefficient = 0.93) between the two variables in the range for specific conductance from 400 to 5,000 $\mu mho/cm$ at 25°C. By using the regression equation represented by the line on the accompanying illustration (fig. 8.2.6-4), sulfate concentrations can be estimated at sites in the area downstream of mining from measurements of specific conductance between 400 and 5,000 $\mu mho/cm$ at 25°C.

8.0 SURFACE WATER (Continued)
 8.2 SURFACE-WATER QUALITY (Continued)
 8.2.7 ALKALINITY AND ACIDITY

ACIDITY VALUES ARE HIGHER DOWNSTREAM THAN UPSTREAM OF SURFACE MINING AREAS

Only one site upstream of mining had measurable acidity. Twenty-one sites downstream of mining had acidity values ranging from 0.1 to 99 milligrams per liter (mg/L) as the hydrogen ion (H^+). Alkalinity values ranged from 0 to 390 mg/L as calcium carbonate ($CaCO_3$) at the upstream sites and from 0 to 520 mg/L as $CaCO_3$ at the downstream sites.

Acidity is defined as "the quantitative capacity of an aqueous media to react with hydroxyl ions" and is expressed in mg/L as the hydrogen ion (H^+). It is an important parameter to measure in areas affected by surface mining because when present in significant amounts it is an indication that acid-forming materials are interacting with the surface water. Alkalinity is defined as the capacity of the solution to react with hydrogen ions and is commonly reported in mg/L as $CaCO_3$ even though $CaCO_3$ may not be the source of or be responsible for all the buffering capability.

One site upstream of mining had measurable acidity. Twenty-three of forty-eight sites downstream of mining had measurable acidity that ranged from 0.1 to 99 mg/L as H^+ (fig. 8.2.7-1 and 8.2.7-2 and table 8.2.7-1).

Alkalinity at sites upstream of mining ranged from 0 to 390 mg/L as $CaCO_3$ with a mean of 92 mg/L as $CaCO_3$. The sites downstream of mining had a range in alkalinity from 0 to 520 mg/L as $CaCO_3$ with a mean of 88 mg/L (fig. 8.2.7-1 and table 8.2.7-2).

Although mean values for alkalinity at the upstream and downstream sites are similar (fig. 8.2.7-3) variations between sites, especially downstream of mining, are great. Surface mining exposes not only the pyrites and marcasites (acid-forming materials) but also the limestones (source of $CaCO_3$) of the Pennsylvania System. The variability of alkalinity values at the sites downstream of mining may depend on the amounts of limestone exposed during mining.

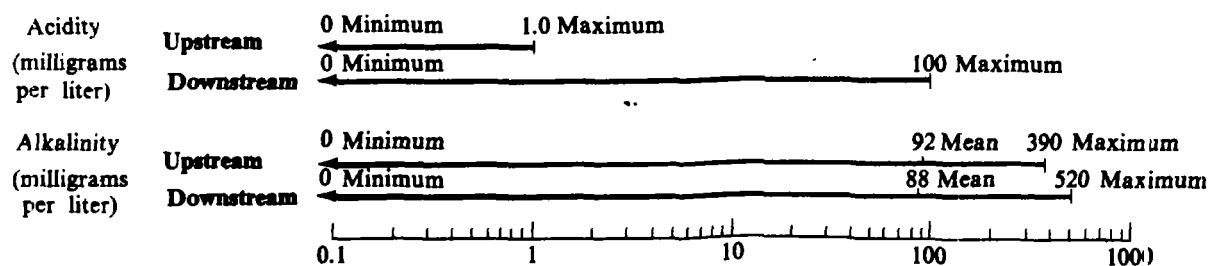


Figure 8.2.7-1 Range of acidity and alkalinity values at sites upstream and downstream of mining

8.0 SURFACE WATER (Continued)

8.2 SURFACE-WATER QUALITY (Continued)

8.2.8 TRACE ELEMENTS AND OTHER CONSTITUENTS

**CONCENTRATIONS OF TRACE ELEMENTS
VARY IN THE STUDY AREA**

Concentrations of many trace elements and other water-quality constituents differed between sites upstream and downstream of surface mining.

Concentrations of many dissolved constituents differed between sites upstream and downstream of mining as shown in figure 8.2.8-1. In water, copper, zinc, boron, calcium, nickel, magnesium, and aluminum all had higher mean concentrations downstream of mining than upstream. Concentrations of carbon dioxide in

water and total iron in the bottom material were also higher downstream of mining. Mean concentrations of total manganese in bottom material showed little difference between upstream and downstream sites. Dissolved chloride concentrations were less downstream than upstream of mining.

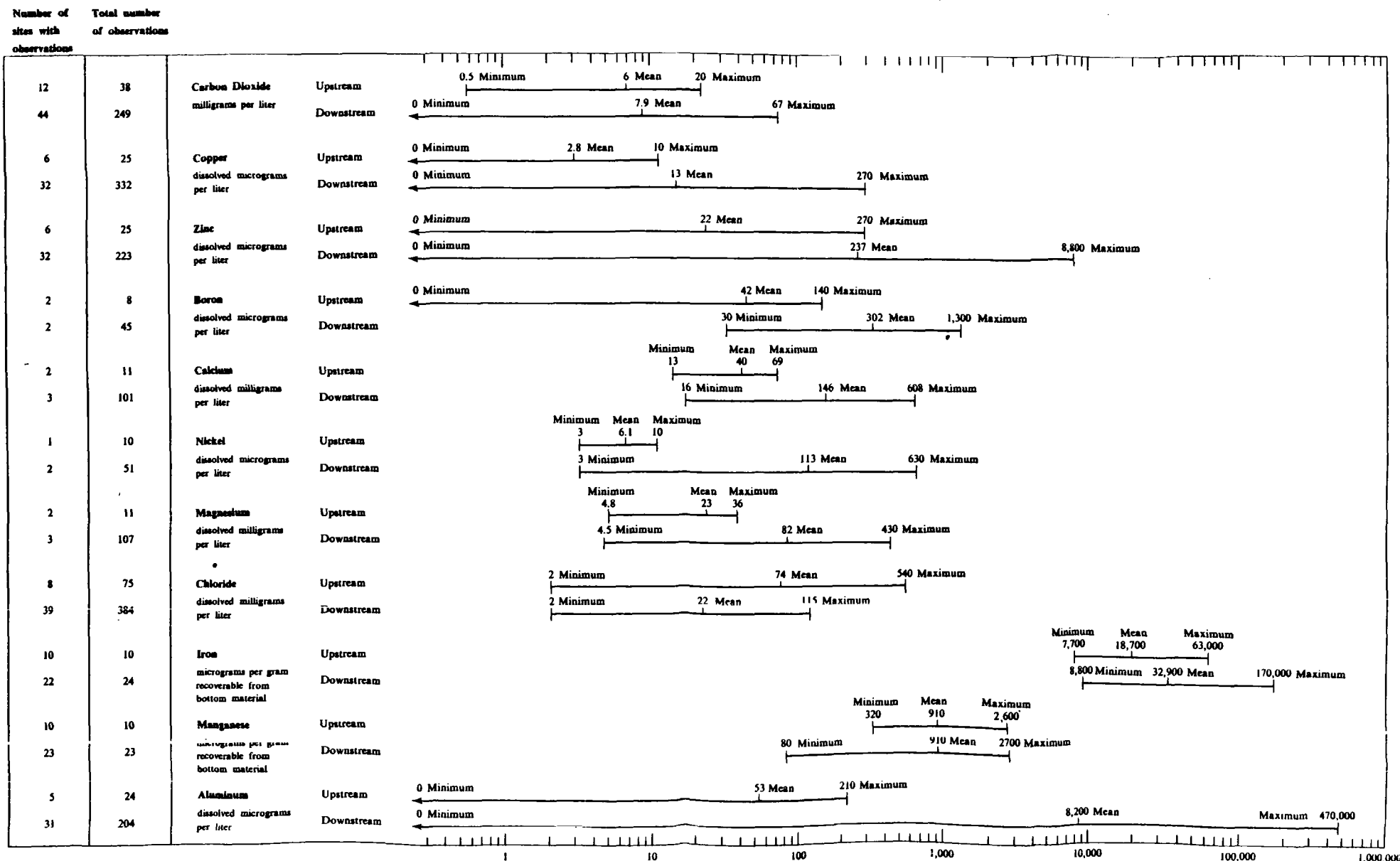


Figure 8.2.8-1 Range of concentrations for various constituents at sites upstream and downstream of mining.